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An Economic Analysis of Adoption of Integrated Pest Management in Groundnut

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I

INTRODUCTION

Groundnut (*Arachis hypogea*, L.) is an important oilseed crop grown in India. The crop is grown mostly during *kharif* under rainfed conditions and it occupied about 6 mha with a production of 8.2 mt in 2003-04 (Government of India, 2006). The average yield levels of groundnut in India are lower than the potential yields as well as the world average yields.[1] Abiotic stress, as the crop is grown under rainfed conditions and biotic stress are the important factors behind such low levels of productivity. Among various biotic stress causing agents, incidence of insect pests is more important. Dependence on chemical insecticides for controlling the insect pests has led to environmental and economic ill-heath in addition to being ineffective as the pests have developed resistance (Armes *et al*., 1997). As a response, researchers and extension systems have been trying to develop and transfer what are called integrated pest management (IPM) practices. The IPM basically intends to manage the pests below the economic threshold levels (ETL)[2] by resorting to a variety of management practices (FAO, 1971). Use of minimum levels of safer, less persistent[3] insecticides is allowed depending on the need in IPM (Perfect, 1992). There is not much information available on the adoption of IPM practices and the impact thereof in the case of groundnut. This paper attempts to analyse the determinants and impact of adoption of IPM practices in groundnut.

II

DATA AND METHODOLOGY

This study is a part of a project “Assessment of Adoption and Impact of IPM in Rainfed Crops” funded by the Indian Council of Agricultural Research. The data with

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respect to groundnut were obtained from the farmers in Anantapur district of Andhra Pradesh. Groundnut is extensively (more than 70 per cent of cropped area) grown in this district (Government of India, 2006). Three villages, where efforts to promote IPM technologies were made in the past, were purposively selected in consultation with the Krishi Vigyan Kendra (KVK), NGOs and the state Department of Agriculture.

The selection of farmers was random and interactive. First, a farmer was randomly selected from the list of all the farmers growing groundnut in the village. It was then ascertained what pest management practices he or she was following. Depending on the response, the farmer was classified either as an IPM-adopter or as a non-adopter. For this study, a farmer was considered to be adopting IPM if he or she followed at least four different pest control technologies. The farmers who were largely dependent on chemical insecticides were considered as non-adopters.[4] This process was repeated thus a sample of thirty IPM-farmers and thirty non-IPM farmers in each village were selected, making a total sample of ninety adopters and ninety non-adopters. Data related to farm and household characteristics, adoption of pest management technologies, inputs use, productivity and prices were obtained using a pre-tested schedule following the interview method. The interviewer is an entomologist trained in conducting interviews for obtaining information from the farmers. The data related to the agricultural year 2004-05.

Analysis of Factors Influencing Adoption

Adoption can be defined in two ways (Feder *et al*., 1984). First, it can be considered as a dichotomous measure when the number of farmers following a particular technology is considered. Secondly, it can be considered as a continuous variable when viewed as a degree of use (quantity of fertiliser per hectare, degree of adoption of IPM components, percentage of farmers using a technology). In this paper, we attempted to assess adoption in both 'whether' and 'extent' terms. We first attempted to analyse the factors that influence the adoption decision. Then, we tried to measure the extent of adoption of the technology, the IPM in this case, by the adopters.

The decision to adopt or not to adopt the IPM essentially takes the form of a binary variable and therefore can be analysed with logit or probit models (Harper *et al*., 1990). These models relate the dependent and the independent variables non-linearly (Gujarati, 2004). The multivariate logistic regression models have been used to analyse the farmers' adoption decision with respect to different technologies (Harper *et al*., 1990; Rama Rao *et al.*, 1997; Sharma, 1997; Adesina and Chianu, 2002).

The decision of a farmer to adopt or not to adopt a technology is influenced by a variety of factors related to the farmer (decision maker) and the farm. In this study, the decision to adopt IPM was regressed on a set of independent factors, viz., farmers' age (X_1), education (X_2), family labour availability[5] (X_3), participation in social groups (X_4), ability to recognise the pests and natural enemies (X_5), farm size (X_6), proportion of area under the pigeonpea (X_7), and access to irrigation (X_8). Considering that IPM components do not require high cash investments, access to and use of credit was not included in the model.[6] In the study villages, extension agencies such as KVK, NGO and Department of Agriculture have worked to promote IPM technologies. During this process, efforts were made to interact with all the farmers individually or in groups. Thus, all farmers were assumed to be uniform with respect to access to extension which is why it was not considered in the model.[7] The specification and measurement of these variables are given in Table 1. Since the dependent variable, the adoption of IPM, is a binary variable, and the independent variables are a mix of qualitative and quantitative variables, the multivariate logistic regression as given below was used to examine the influence of these factors on the adoption decision.

$$Y = \text{Ln}\,(P/(1-P)) = \beta_0 + \sum\beta_i X_i \quad (i=1 \text{ to } 8)$$

where P is the probability that the farmers adopts IPM and (1-P) is the probability that the farmer does not adopt the IPM and the βs represent the regression coefficients estimated by the maximum likelihood method. These coefficients represent the change in the log of odds of adoption of IPM for a unit change in the corresponding independent variable. We computed the e^{β}, which gives the odds ratio, associated with change in the independent variable. The analysis was done using SPSS12.0 software.

TABLE 1. SPECIFICATION AND MEASUREMENT OF INDEPENDENT VARIABLES INCLUDED IN THE LOGISTIC REGRESSION MODEL

Variable (1)	Unit (2)	Measurement (3)
Age of the farmer	Years	Farmer's response to the question.
Education	Years of schooling	Farmer's response to the question.
Family labour availability	Number of adults in the household	Number of adult members in the household, expressed in male equivalents. One female adult is considered equivalent to 0.67 male adult. Any individual over 14 years of age is considered as an adult.
Participation in social groups/community based organisations	Dummy variable, 1 if participating and 0 if not.	Ascertaining if the farmer is a member of any CBO such as SHG, UG, PRI etc.
Ability to recognise the pests and natural enemies	Numerical score	Farmers were asked whether they can identify the pests and natural enemies by asking to describe the organisms with respect to their appearance, feeding behaviour, damage symptoms etc. The local names of the organisms and photographs were made use of for the purpose.
Farm size	ha	The size of the land holding operated by the farmer.
Proportion of area under groundnut	Per cent	The ratio of area sown to groundnut to the total farm size.
Access to irrigation	Per cent	Ratio of irrigated land to the total land operated by the farmer.

Measuring the Extent of IPM Adoption

The adoption can be measured as the extent or degree of adoption also. IPM is a continuum spanning from complete dependence on chemical insecticides at one end to a combination of a wide range of cultural, mechanical, biological and chemical means at the other. In order to understand the extent of IPM adoption, we attempted to measure IPM adoption as a weighted score. The weighted scores were computed as follows: First, a list of all the plant protection practices followed by the IPM farmers was developed. Then, these practices were divided into four categories – cultural, mechanical, biological and chemical. These categories were given different weights considering their importance in IPM. Thus these four categories were given weights of 0.30, 0.20, 0.35 and 0.15, respectively. These weights were arrived at in consultation with the entomologists working on pest management in groundnut.[8] Then, the number of practices followed in each category was multiplied by the respective weight and summed over all the categories to obtain a weighted score of IPM adoption for the farmer. Thus, the IPM score, Z, of a farmer is given by

$$Z = \Sigma w_j n_j$$

where w = weight of the j-th category (j=1 to 4);
n = number of practices belonging to the j-th category adopted by the farmer.

After computing the individual IPM scores, farmers were divided into three categories – low, medium and high adoption – by taking the 35 and 70 percentile scores as cut-off points. Thus, farmers whose scores were equal to or below 35 percentile were categorised as low adopters, those falling between 35 and 70 percentile were categorised as medium adopters and those scoring greater than 70 percentile were classified as high adopters.

Farm Level Impact of IPM

The impact of adoption of IPM technologies is examined by following a ‘with and without’ approach where in the mean values of the key parameters such as the use of plant protection chemicals, cost of cultivation, yield, net returns, of the ‘IPM’ farmers were compared with those of the non-IPM farmers. The differences were tested for their statistical significance applying t-test for continuous variables (inputs use, yield etc.) and χ^2 test for categorical variables (number of sick events).

III

RESULTS AND DISCUSSION

Adoption of Different IPM Components

Different components of IPM recommended for groundnut and the frequency of adoption of each practice are given Table 2. It can be observed there were wide variations in the adoption of different components of IPM. Application of chemical insecticides is the most adopted with 92 per cent of the farmers adopting it. Practices such as deep ploughing, intercropping with cowpea or black gram, growing border crop, treating the seed with insecticides or fungicides, early sowing of the crop and application of botanical insecticides such as Neem Seed Kernel Extract (NSKE), neem oil etc. are among the highly adopted IPM components with more than 60 per cent of the farmers adopting each of these practices. Application of Nuclear Polyhedrosis Virus (NPV), *Bacillus thuringiensis* (Bt) is an important component of IPM. Its adoption was however low at two per cent. The limited availability of these inputs is an important reason for their low adoption. Keeping light traps is one of the key recommendations for managing the red hairy caterpillar in groundnut. The practice was found to be adopted by about 39 per cent of the farmers. The adoption frequencies for pheromone traps, erection of bird perches and mechanical collection were 15.3, 14 and 11.3 per cent respectively. The adoption of other components of IPM was very low as many farmers were not aware of these practices.

TABLE 2. ADOPTION OF DIFFERENT COMPONENTS OF IPM IN GROUNDNUT IN ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05 (N=180)

IPM component (1)	Adopters (per cent) (2)
Biological components	
Pheromone traps[a]	15.3
Spraying of NSKE, neem oil etc.	62.3
Application of NPV, Bt etc.	2.0
Chemical components	
Seed treatment	67.3
Digging trenches around and application of dust	0.6
Poison baiting with monocrotophos	0.7
Insecticide spray (endosulfan or quinolphos)	92.0
Spraying on non-crop host plants	25.3
Cultural components	
Early sowing	62.7
Deep ploughing	82.0
Crop rotation	2.7
Trap crop with cucumber[b]	0.7
Vegetative traps with *Ipomoea, Calotropis* etc.	0.7
Intercropping with cowpea or black gram	70.7
Mulching with rice straw	0.67
Close planting	18.0
Border crop	63.3
Erection of bird perches[c]	14.0
Removal of congress weed	3.3
Mechanical components	
Keeping light traps[d]	38.7
Collection and killing of adult moths	5.3
Manual collection of grubs from manure sources	6.0

a - These contain synthetic pheromones which generally attract and trap male insects like *Spodoptera litura*.
b - Trap crops are more attractive to the pests than the main crops. When the pest in concentrated in trap crop, it is removed.
c - These are T-shaped bamboo stakes that attract birds which predate on the insect pests.
d - These are used to trap and kill the phototropic insect pests like red hairy caterpillar in groundnut.

Factors Influencing Adoption

The characteristics of IPM farmers and non-IPM farmers are presented in Table 3. It is seen from the table that the average age of the IPM adopters was about 41 years compared to 46 years in case of non-adopters. The IPM farmers on an average had 5.5 years of schooling. The IPM adopters and non-adopters did not differ significantly in terms of farm size and irrigated area. A larger number of IPM adopters were members in some community based organisations (CBOs) such as farmers' clubs, user groups, self help groups etc. The IPM farmers also could identify more number of pests and natural enemies than the non-IPM farmers. IPM farmers have sown about 96 per cent of land to groundnut compared to 97 per cent in case of non-IPM farmers. The average farm size of IPM farmers was about 8.6 ha compared to 8.9 ha in case of non-IPM farmers.

TABLE 3. CHARACTERISTICS OF IPM ADOPTERS AND NON-ADOPTERS IN GROUNDNUT IN ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05

Variables (1)	Unit (2)	IPM (n=90) (3)	Non –IPM (n=90) (4)
Age	Years	41.2 (8.7)	45.7 (8.7)
Literacy	Per cent	5.5 (3.3)	1.6 (2.1)
Adults	No/HH^{-1}	3.6 (1.6)	3.8 (1.6)
Children	No/HH^{-1}	1.8 (0.9)	1.3 (0.8)
Membership	Per cent	72	62
Ability to identify pests	Score	6.2 (1.1)	5.6(1.5)
Farm size	Ha	8.6 (9.0)	8.9(7.2)
Area under groundnut	Per cent	96.4 (9.7)	97.1(15.0)
Irrigated areas	Per cent	3.8 (9.7)	2.8 (9.8)

Figures in parentheses are standard deviations.

The maximum likelihood estimates of the logistic regression model obtained with SPSS 12.0 are presented in Table 4. The table gives the estimated regression coefficients along with the significance levels, the odds ratio and the model fit statistics in the form of Negelkerke R^2, log likelihood and the per cent correct classification. The model estimated was found to be a significantly good fit as can be seen from all the three criteria mentioned. The Negelkerke R^2 was about 0.52 and the log likelihood (-2 log LL) of 160.69 was significant at one per cent. The model predicted about 76 per cent of the cases correctly as either adopters or non-adopters. Further, the model predicted 77 per cent of adopters and 79 per cent of non-adopters correctly.

The logistic regression results presented in Table 4 indicate that education of the farmer, number of adults in the household, participation in CBOs and ability to recognise the pest and natural enemy species and farm size influenced the adoption decision significantly. As can be seen from the table, each year of schooling increased the odds of adoption of IPM by 58 per cent (an odds ratio of 1.58).

TABLE 4. LOGISTIC REGRESSION RESULTS FOR ADOPTION OF IPM IN GROUNDNUT, ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05

Variable (1)	β (2)	SE (3)	Wald (4)	OR (5)
Constant	0.36	2.47	0.02	
Age	-0.03	0.02	2.13	0.96
Education	0.46**	0.08	32.36	1.58
Adults	0.39@	0.26	2.30	1.48
Membership	0.22*	0.14	2.47	1.24
Ability to identify pests	0.36*	0.15	5.57	1.44
Farm size	-0.08**	0.03	7.07	0.93
Area under groundnut	-0.02	0.02	0.92	0.98
Irrigated area	0.02	0.02	0.55	1.02
Negelkerke R^2		0.52		
-2 log L		160.69		
Per cent correct classification[a]		77.7		
Specificity[b]		76.7		
Sensitivity[c]		78.7		

**, * and @ indicate level of significance at 1,5 and 10 per cent, respectively.
a - Based on a 50-50 classification scheme.
b - Per cent of adopters predicted correctly.
c - Per cent of non-adopters predicted correctly.

Similarly, as the age of the farmer increased by one year, the odds would decrease by four per cent. Thus, the younger and educated farmers are more likely to adopt IPM technologies. The participation in social groups also influenced the adoption decision significantly. A farmer who is a member in some CBO is 1.24 times more likely than a farmer who is not a member. The participation of a farmer in social groups enhances his or her social capital in terms of access to information and resources. Further, various development programmes are also emphasising the technology transfer through self-help groups, user groups, etc., to quicken and broad base the uptake of the technologies. Thus, the highly positive and significant influence of the social capital as represented by participation in social organisations is tenable. Scouting for insect pests is an important component of IPM and this requires that farmers are able to identify the insect pests and natural enemies in their farm. The probability of adoption of IPM was found to increase by 44 per cent when the score capturing the ability to identify the pests increased by one unit. The IPM technologies require more labour compared to the dependence on chemical insecticides alone. Thus the bigger farms and larger acreage under groundnut are less likely to attract IPM, which is reflected in the negative coefficients of the farm size and the area under groundnut. The significantly positive coefficient for labour endowment as measured by the number of adults per household supports this observation. It may be of relevance to note that farmers with larger farms and more area under the crop concerned are more likely to adopt chemical plant protection measures as observed in the case of castor (Rama Rao *et al.*, 1997). Access to irrigation is positively associated with the use of higher chemical inputs and thus assumed to discourage adoption of IPM. However, the influence of access to irrigation was not found to be significant, probably because of the lower extent of irrigation.

Extent of Adoption

In the above analysis a farmer was considered to be an IPM adopter if he or she adopts at least four different components of IPM. However, there can be variations in the extent of adoption of different components of IPM. In order to measure the extent of adoption, scores were computed for all the IPM farmers. The findings are presented in Table 5. Twenty two different components of IPM were observed to be followed by the IPM farmers. As many as eleven of these twenty two were cultural practices, four were chemical, four biological and three mechanical. A farmer adopting all these twenty two practices in his or her effort to manage pests below the economic threshold levels, he or would get a score of 5.7. The scores of the farmers were found to vary between 1.4 and 3.8 with an average score of 2.16. About 55 per cent of the farmers scored below 2.05 (35 percentile) and were classified as low adopters (Table 6). Only 6 per cent of the farmers classified as high adopters (>70 percentile) were found to achieve high adoption scores (>2.70). The remaining 40 per cent of farmers were classified as medium adopters with scores between 2.05 and 2.70. Thus there was variation in adoption observed within the adopters and a majority of the farmers were found to operate at low levels of IPM.

TABLE 5. EXTENT OF IPM ADOPTION IN GROUNDNUT IN ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05

Category (1)	Weight (2)	No. of practices followed (3)
Total	1.00	22
Chemical	0.15	5
Cultural	0.30	11
Biological	0.35	3
Mechanical	0.20	3
Maximum possible score		5.7
Mean score		2.16
Range		1.4 – 3.8

TABLE 6. DISTRIBUTION OF FARMERS INTO DIFFERENT CATEGORIES OF IPM ADOPTION, ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05

Category (1)	IPM Score (2)	Number (3)	Per cent (4)
Low (<35 percentile)	<2.05	98	54.4
Medium (35-70 percentile)	2.05 – 2.70	72	40.0
High (>70 percentile)	>2.70	10	5.60

Farm-Level Impact of IPM

As mentioned earlier, the farm-level impact of the IPM was observed by comparing the use of chemical insecticides, cost of cultivation, nutrient use and yields of IPM farmers with those of non-IPM farmers. As a result of adoption of IPM components, a steep decline was observed in the use of chemical insecticides from about 16 l ha^{-1} in the case of non-IPM farmers to about 6 l ha^{-1} in the case of IPM farmers (Table 7). Consequently, the expenditure on plant protection chemicals fell from Rs. 3,619 to Rs. 1,084 ha^{-1}. It is interesting to note that the IPM farmers also applied about 84 per cent more organic manures compared to the non-IPM farmers. The IPM farmers harvested about 9.8 q/ha of groundnut compared to 9.2 q/ha in case of non-adopters. The reduced cost of cultivation and marginally higher yields together resulted in higher net returns from IPM farms (Rs. 7,246 ha^{-1}) compared to non-IPM farms (Rs. 3,651 ha^{-1}). Another important benefit of IPM adoption is the reduction in the incidence of health hazards associated with the use of chemical insecticides. About 5 per cent of farmers reported pesticide-related health hazards compared to 17 per cent in case of non-IPM farmers. Such a reduction is due to the less number of chemical sprays as well as due to the relatively safer insecticides used by the IPM farmers.

TABLE 7. FARM-LEVEL IMPACT OF ADOPTION OF IPM IN GROUNDNUT IN ANANTAPUR DISTRICT, ANDHRA PRADESH, 2004-05

Parameter (1)	Unit (2)	Non-IPM farms (3)	IPM farms (4)	Change (per cent) (5)	t statistic (6)
FYM	t ha^{-1}	10.6	19.4	83.5	2.13
Nutrients	kg ha^{-1}	88.0	77.3	-12.2	6.09
Insecticides	l ha^{-1}	15.7	5.8	-63.2	7.67
Yield	q ha^{-1}	9.2	9.8	6.4	4.04
Expenditure on insecticides	Rs^{-1}	3619	1084	-70.1	8.72
Cost of cultivation	Rs ha^{-1}	11791	9366	-20.6	2.34
Net returns	Rs ha^{-1}	3651	7246	98.5	2.66
Incidence of sick events	Per cent	16.7	5.5		5.62*

The differences were found to be statistically significant at least at 5 per cent.
* χ^2 statistic.

IV

SUMMARY AND POLICY IMPLICATIONS

Considering the importance of pest management in groundnut, this paper attempted to analyse the extent, determinants and impact of adoption of IPM by groundnut farmers in Anantapur district of Andhra Pradesh, India. It was observed that the farmers followed a wide range of pest management practices. Apart from application of chemical insecticides, other practices such as deep ploughing, intercropping, growing border crops, seed treatment, early sowing and spraying of neem based preparations were among the more frequently adopted IPM practices. A logistic regression analysis showed that the decision to adopt IPM was strongly influenced by education, participation of the farmers in community based organisations, labour endowment and ability to recognise the insect pests. These results underline the importance of human and social capital in adopting technologies such as IPM which are knowledge-intensive. It was also observed that a majority of the farmers were operating at lower levels of IPM. Adoption of IPM practices was found to lead to reduction in the use of insecticides, decrease in cost of plant protection and cost of cultivation and increase in net returns. Further, fewer incidents of falling sick due to exposure to insecticides were reported in case of IPM farms compared to non-IPM farms.

From the findings of the present study, the following policy implications emerge. First, since the cultural components of IPM are more readily accepted by the farmers, more research into such components of IPM may enhance the adoption and thereby research productivity. Similarly, non-availability of biological components may be addressed so that the ecologically friendly pest management practices are adopted by the farmers. Secondly, as IPM is a knowledge-intensive technology, research and extension support should be further strengthened for the benefit of the farmers. Any effort to promote IPM should be intensive as well as run for a considerably longer period with commitment from the agencies concerned. Thirdly, the observed positive impact on the economic and health parameters of adoption of IPM warrants continued support in terms of research and extension.

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NOTES

1. During 2001, the average productivity of groundnut in India was 756 kg/ha against a world average productivity of 1374 kg/ha (Government of India, 2004). During 2004-05, the average productivity of groundnut in Andhra Pradesh was 890 kg/ha compared to a potential yield of 1837 kg/ha (Government of India, 2007).

2. The objective of IPM is not to eradicate pest completely, but to keep the pest population levels so low that they cannot cause economic damage. The pest population level which causes economic damage is called the economic threshold level (ETL). In the traditional chemical pest control, ETL is the level of pest incidence at which the value of yield lost due to pest incidence equals to cost of pest control. It is the level at which the pest control measures are initiated.

3. Safer insecticides are those which are specific and selective against a pest and have short and less harmful residual effects. Broad spectrum insecticides are generally avoided in IPM as they can be harmful to the natural enemies of the pest as well.

4. Such a classification of farmers may not be an ideal one but we chose to follow this basis considering that IPM emphasises integration of different means of pest management. Further, initial interactions with the farmers indicated that farmers who were largely dependent on chemical insecticides did not follow other methods of pest management such as biological and mechanical practices.

5. It is the family labour, which is more involved in implementing the IPM practices. For example, preparation of NSKE, NPV or erection of bird perches are generally performed by family labour, mostly by the females. Hence, only family labour was included in the model. Further, inclusion of hired labour in the model did not improve the fit nor was it found to be significant with a coefficient of 0.001 and standard error of 0.004. Use of more hired labour can, in fact, be a consequence, rather than a cause, of adoption of IPM.

6. Most of the IPM technologies recommended for groundnut require little cash investment. The components of IPM such as NPV and NSKE are prepared at household level or generally made available through the agency that promotes IPM. The availability of these inputs with the pesticide dealers is very

limited which is in fact an important constraint to the adoption of IPM. Hence, access to credit is not included as a regressor in the model.

7. A KVK and an NGO have worked in the study villages to promote IPM and efforts were made to interact with the villagers individually and collectively in the process. Hence, farmers were assumed to be uniform as far as access to extension services is concerned. However, as literacy is likely to influence what one learns from the contacts with extension agents, it is included in the model. The hypothesis that the implementing agency had any effect on the adoption was also rejected in the preliminary analysis.

8. The weights are arrived at in consultation with the entomologists. More emphasis is given in IPM to biological and cultural components as they are environmentally safe and easy to adopt, especially the latter. Use of chemical insecticides are given the least priority in IPM and hence least weight. The adoption scores so computed were found to have a significantly negative correlation with the use of chemical insecticides, which is the objective of IPM.

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